ENERGY

28 NOVEMBER 1980 (FOUO 24/80) 1 OF 1

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28 November 1980

USSR Report

ENERGY

(FOUO 24/80)

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USSR REPORT

ENERGY

(FOUO 24/80)

CONTENTS

ELECTRIC POWER

UDC 621.311.25:621.039.001

MEI NUCLEAR POWER RESEARCH

Moscow TEPLOENERGETIKA in Russian No 10, Oct 80 pp 2-4

[Article by Doctor of Technical Sciences N. G. Rassokhin: "Basic Directions of Scientific Research by the Nuclear Power Plant Department at Moscow Power Engineering Institute"]

[Text] The services of the MEI (Moscow Order of Lenin Power Engineering Institute) in training cadres are highly valued: in 1980, the MEI was awarded the Order of the October Revolution. The academic work of the institute is inseparably linked to its scientific research. This applies in full as well to the activities of the department of nuclear power plants at MEI.

Following MEI tradition, the AES department has from the first days of its existence done active scientific research connected with solving problems of raising technical-economic indicators, reliability and safety at nuclear power plants. Work has been done to study thermal-physical and physical-chemical processes as applicable to reactor shape and steam circuitry at both two-loop and one-loop AES's with water-cooled reactors.

It is quite obvious that achieving anything substantial along these lines by engineering science is possible at present only given quite extensive experimental research on further theoretical processing of the results obtained. Therefore, the primary attention of the collective has been focused on creating a modern experimental base for research in both thermal physics and physicochemical processes using the parameters and characteristics of actual installations. This has led to the creation of original heat-exchange/corrosion and hydrodynamic test stands using radio-isotope radioscopy. The experimental base consisted of atmospheric pressure installations, static test stands (no heat carrier circulation) with high and supercritical parameters, dynamic test stands (with heat carrier circulation) for isothermic testing of structural materials and to study hydrodynamics, and dynamic test stands with experimental fuel [heat-generating] sections. Several test stands were equipped with radioscopic devices, but a neutron illumination method developed by the department has recently been introduced.

Circulation loops have been designed, installed and put into operation in combination with experimental reactors (one being the experimental reactor at Budapest Technical University), as have several dynamic circulation loops for experimental research both under isothermic conditions and with heat exchange given reactor radiation of varying intensity and with varying neutron spectra.

The installations currently in operation were created and began operating in the 1970's, and their improvement continues to this day.

The department is also conducting experiments at industrial installations at the Beloyarskaya, Novovoronezhskaya, Leningrad, Chernobyl'skaya and Shevchenkovskaya nuclear power plants, the Kostromskaya GRES, the MEI TETs and other industrial enterprises. Modern research laboratories have been created to research various materials of models tested on test stands, to determine the characteristics of the heat carrier, develop experimental materials for both physicochemical and thermal-physics experiments, as well as to research mathematical models. Among them are the optical and electron microscopy laboratory, the X-ray structure laboratory, the electrochemical and chemical-analytical analysis laboratory, and a reactor kinetics laboratory equipped with simulating analog and digital computers. Finally, creation of a computer center consisting of a unified-series model 1022 computer will be complete by the 25th anniversary of the department, and we subsequently propose to link it to the institute's main computer center.

Development of the experimental laboratory base was determined by the dynamics of scientific research development. In the initial years, in spite of limited material-technical opportunities, the department collective did original research devoted to studying the corrosion resistance of austenite stainless steel. One feature of that research was experiments using parameters characteristic of the operating conditions for parts made of these steels, as well as the combining of static (autoclave) experiments with resource testing in circulation circuits. The results obtained made a definite contribution to our understanding of the mechanism of corrosion spallation and enabled us to offer recommendations on the reliability of the structural formation of certain steam-generation installation elements. It was precisely this work that laid the foundation for the new scientific direction of studying the interaction of structural materials in the heat-transfer agent. In this area, research has been done on the corrosion-erosion stability of nuclear power installation elements under the most diverse conditions. Among the completed work, we should note research on the efficiency of heat-transmitting surfaces made of zircon material given surface rimming and high heat flows. Analogous research was done on other materials, including stainless steels. It revealed new factors determining the reliability and economy of operation of nuclear power installations. Thus, research results for the corrosion resistance of austenite stainless steels showed the necessity of replacing it with other heat-transfer agents less demanding as to quality, more efficient, and, particularly importantly, relatively inexpensive. The initiator of work on replacing austenite stainless steel with perlitic steels was Doctor of Technical Sciences T. Kh. Margulova. In working on the problem, primary attention was focused on creating methods of passivating carbon steel. The MEI method was based on creating strong protective films when working carbon profiles using complexones. One important feature of this research is that it studied behavior patterns given thermic and radiation influence by both the complexones themselves and the iron complexes formed by them. This research enabled us to broaden substantially opportunities for using complexones, including the possibility of preventing and washing off incrustations and of decontaminating AES equipment. For their work in the area of using complexones in ordinary and nuclear power engineering, doctors of technical sciences T. Kh. Margulova and N. G. Kassokhin and Candidate of Technical Sciences A. S. Monakhov were awarded the USSR State Prize in 1978.

The AES department carries out a broad range of research connected with studying the patterns of incrustation in the cooling system, with working out steps to prevent it and effective methods of removing it. This research is also done in a comprehensive manner, using various experimental installations and reactor loops, and the results are subsequently checked at industrial installations. The MEI method of washing off incrustations has already successfully undergone industrial testing and has been extensively introduced into practice.

In close connection with these research efforts is work to develop an optimum water system for reactors, steam generators and AES's as a whole. The results of water system research confirm most graphically the effectiveness of the principle adopted by the AES department of closely combining comprehensive laboratory experiments with industrial testing. Typical of the AES department's water system research has been the fact that the bulk of the industrial research has been done at a GRES with supercritical parameters, since the condensate and feed water quality there is practically identical with that at an AES. Setting up scientific research this way has important features -- ordinary thermal power engineering gains from the introduction of progressive new water systems, and transferring them to nuclear power engineering is more reliable after a long check-out period at a GRES. Thus, resolutions connected with optimizing 100-percent condensate purification were initially tested and introduced by the AES department at the Kostromskaya GRES and were then transferred to a similarly shaped AES with an RBMK-1000. A similar situation developed with chemical purification technologies -- prestart-up, operational and "running." Treatment methods developed in AES department laboratories were introduced at ordinary TES's and were then transferred successfully to AES conditions. Research in the water-system area which is done directly on large AES reactors is of great scientific and practical interest. First, we must note research on the behavior of hydrogen peroxide in the reactor loop. We proved for the first time under actual conditions the existence of hydrogen peroxide in reactor water even at full capacity and revealed the positive role of hydrogen peroxide in reducing corrosion in steels. This work enabled us to transfer the nuclear power experiment to thermal power generation. Thus, blocks with doses of different oxidizers, hydrogen peroxide and gaseous oxygen, were researched under comparable conditions for the first time at the Kostromskaya GRES. In combination with laboratory experiments in this area, the AES department proved the fallacy of views held by FRG power engineers to the effect that doses of hydrogen peroxide were only a "convenient method of introducing oxygen."

In this water system work, we should also mention theoretical (thermodynamic) research done on the behavior of iron hydroxides as a function of condensate temperature and alkalinity. This research explained the observed preferential sorbtion of iron on anionite, rather than cationite, which is important in loading condensate purification filters efficiently; such filters are a mandatory element both at TES's with supercritical parameters and at single-loop AES's.

In connection with the fact that the reliability and economy of nuclear power plants is closely linked to thermophysical processes, hydrodynamics and heat exchange problems occupy an important place in scientific research at the AES department. At the same time, these processes are intimately associated with physicochemical ones, and in particular, with those examined above. The department's earliest work in the area of thermophysics was devoted to researching the hydrodynamics of bubbling two-phase streams. The data obtained in it on transition region height and its connection with calculated phase speeds and bubbler diameter, as well as data on steam phase capture in down sectors, found a place in the development both of steam generator and boiling-water reactor separation systems and of calculations of the reliability of the circulation in them. This work was subsequently transferred to the field of the hydrodynamics of single-phase, abruptly-boiling and two-phase streams under a variety of conditions as are possible in individual reactor loop elements.

The AES department is one of the first scientific organizations to have initiated research in this area. Along with concrete data needed for planning and designing hydrodynamic systems, this work has provided rich scientific methods material, in particular concerning methods of γ-illuminating two-phase streams.

As is known, a precise knowledge of hydrodynamic conditions when fuel assemblies are washed over by a heat carrier is very important in reactor engineering. The AES department has done a great deal of research to determine the true steam content Φ as applicable to conditions in the active zones of boiling-water and water-cooled reactors given surface boiling. Especially important in this research is the development of a precise method of determining local value Φ. In this area, much work has been done to improve γ-illumination methods so as to create a special, original neutron illumination method. Extensive experimental data on the dependence of Φ on the various operating conditions and flow parameters have found broad application in various branches of engineering which use heat-exchange equipment. Heat-exchange work was initially done in the AES department to meet our "own needs." In the 1960's, there were no experimental data or calculation recommendations on determining thermal conditions for testing materials in accepted experimental sector designs. We therefore had to conduct a series of original research on heat exchange in circular passages, both for the usual turbulent water flow and for surface and thorough, hard boiling.

As a consequence, research was done on the heat-exchange patterns and critical heat flows in circular passages for which the presence of deposits, including iron oxides, in the heat-generating pipes was an original feature. The results of this research provide an accurate representation of the reliability of heat-fixing surfaces given the presence of deposits with various characteristics on them. Data were also obtained on the patterns of deposit formation, their thickness and effective heat conductivity as a function of the thermal, hydrodynamic and physicochemical conditions in the loop.

Work begun more than 10 years ago to study VVER [water-cooled power reactor] AES emergencies led to the creation of a promising research line, studying the transient hydrodynamics of a two-phase flow. The applied work of the initial stage included research on the following problems:

hydrodynamics of single- and two-phase flows in complex systems if the main circulation pumps are dead;

transient hydrodynamics if the main circulation pipeline is cut off from the first AES loop.

The tasks set early in this work were to create calculation models and, based on them, programs which would satisfy developers of promising new AES units (VVER-440, VVER-1000). However, experience showed that this task would require a great deal of experimental work in the area of transient hydrodynamics of a two-phase flow, since there were practically no experimental data, or were clearly inadequate data, on the following problems:

escape of a two-phase flow through openings and pipes under transient conditions;

wave processes given a meta-stable state of water incompletely heated to saturation temperature;

the physics of water and steam dissociation if pressure drops.

Two experimental installations were developed and created to study these phenomena. The second of them is unique in its potential, since it is equipped with a γ-illumination system which enables us to study the structure of a two-phase flow under dynamic conditions.

The experimental data obtained on it have permitted a substantial improvement in the level of calculation methods and have yielded important practical recommendations for developers of AES safety systems.

Original research has been done on heat-exchange patterns for repeated wetting of heating surfaces as applicable to water heat-carrier reactor cooling conditions. This research has been oriented towards obtaining calculation patterns, primarily for creating reliable, effective water heat-carrier reactor emergency cooling systems. Moreover, the experimental data obtained are necessary for studying the complex heat exchange mechanism represented by repeated wetting of heating surfaces, for which there is very little data at present. It should be noted that studying heat exchange in emergency cooling has led to the development of a comprehensive approach to studying the effectiveness of emergency cooling systems, one based on determining their functional and structural reliability. Such an approach enables us to find effective ways of optimizing such important AES protection features as the emergency cooling systems for reactors with a water heat-carrier.

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ELECTRIC POWER

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STANDARD VVER-1000 AES SAFETY SYSTEMS

Moscow TEPLOENERGETIKA in Russian No 10, Oct 80 pp 5-8

[Article by Candidate of Technical Sciences V. P. Tatarnikov, "Teploelektroproyekt" All-Union State Planning Institute: "Safety Systems for AES's With A Standard VVER-1000 Reactor"]

[Text] One of the main types of reactors planned for use in USSR AES's is the VVER [water-cooled power reactor]. Available experience in operating power units with this type of reactor testifies to the fact that all those operating in the USSR or built with USSR assistance abroad are operating stably, that planned indicators are being sustained. The installed capacity use factor has reached 80 percent. As an example, one could cite the AES built with USSR technical assistance in Finland. The high reliability of operation of this AES is indicated by the fact that during the period of its commercial operation, the drop in electric power output due to unplanned equipment down time in the machinery hall has been only about 5,000 mW-hr.

In warranty tests, specific heat expenditure was 11,098 kJ/(kW-hr), with a planned expenditure of 11,946 kJ/(kW-hr), and the maximum power (net) was 445.7 MW, as against a planned power of 420 MW, that is the thermal efficiency of the unit was 7.1 percent above that planned and its (net) power was 8.0 percent higher than planned.

Tests run after 22 months of commercial operation revealed practically no deterioration in AES thermal efficiency. During power unit operation, no thinning of the fuel elements was observed and the appearance of fission products in the main circulation loop was determined to be simply a result of fuel element surface contamination.

The USSR manufactures equipment and builds AES's with VVER reactors with an electric power output of 440 and 1000 MW.

The 440-MW power units have been installed at the Armenian, Kol'skaya, Novovoronezhskaya and Rovenskaya AES's. Such power units have been and are being built in the GDR, Hungary, Bulgaria, Poland, Czechoslovakia and Finland. The geographic, climatic, geologic and other conditions in areas where VVER-440 AES's are being built differ substantially, so we had to restrict ourselves to standardizing the basic planning resolutions, rather than creating a standard AES plan. At the same time, experience shows that even the use of standard plans which are altered not more than once every 7-10 years enables us to build power units in acceptable periods (5-6 years), to ensure that they are provided with sets of equipment at the proper time, and to organize a well-planned construction industry. Given stability of the power system in the European portion of the country, power units up to 2,000 MW and larger can be installed in it. The geographic conditions in the central regions of the European USSR are similar, which creates good conditions for the extensive construction of standard AES's with VVER-1000's.

In 1980, the fifth unit at Novovoronezhskaya AES, with its 1,000-MW VVER lead reactor, began operating. The work done showed that the planned indicators of the power unit will be achieved. Based on power unit development and construction in the USSR, a plan has been drawn up for a series-produced 1,000-MW power unit.

The main specifications for the standard power unit are as follows:

Gross electric power	1,000 MW
Overall efficiency	33.3 percent
Annual electric power output	5,960,000 kW-hr
Electric power expenditure to meet own needs	5.2 percent
Steam pressure beyond the generator	6.0 MPa
Steam parameters after industrial heating	1.16 MPa (250°C)
First-loop heat-carrier temperature	322/289°C
First-loop heat-carrier pressure	16 MPa
Coolant expenditure (four loops)	57,000 t/hr
Pressure in turbine condenser	0.004 MPa
Steam generator productivity	1,470 t/hr
Pipeline capacity	1,000 MW

The nuclear fuel is uranium dioxide enriched with 4.4 or 3.3 percent U-235.

Increasing the unit capacity of power units for VVER AES's forces us to be more demanding as to their safe operation. AES safety is regulated by norms and rules, the foremost being "General Provisions on Ensuring Nuclear Power Plant Safety During Planning, Construction and Operation," "Nuclear Safety Regulations," "Temporary Norms for Planning Nuclear Electric Power Installations for Seismic Regions" and so on.

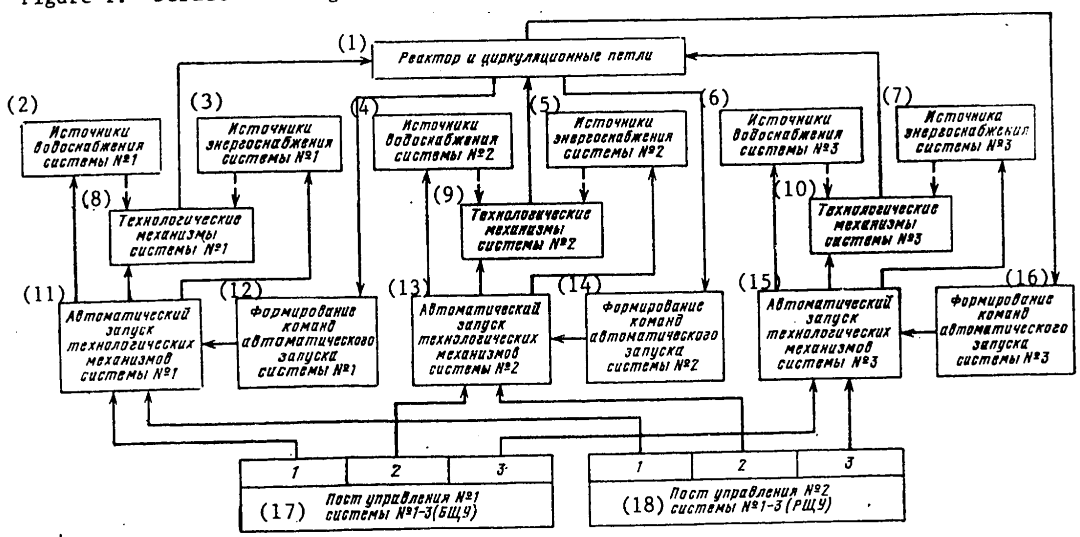
The exacting requirements of these norms and regulations determine the necessity of planning AES's for such natural occurrences as earth tremors, hurricanes, floods, landslides, and so forth, if they are likely to occur at least once every 10,000 years. AES's are also designed for conditions associated with human activity. It is necessary to take into account the coincidence of these effects in planning for maximum depressurization of the reactor circulation loop. Consideration is also given to the possible coincidence of four emergencies -- accident in a system operating normally, undiscovered and long-standing defect in a normally operating system, failure of the safety system and failure of the accident containment system. In this regard, multiple failures caused by a single occurrence are viewed as a single emergency. For example, fire in the power plant might cause numerous failures.

All possible fires are examined, including one in the power unit control panel which causes it not only to lose all functions, but to issue incorrect commands to the control system.

In this connection, the power units include a back-up control panel which can stop the power unit and make it safe.

In order to prevent false commands from reaching the AES safety systems in case of fire or operator error, when there is an emergency at an AES, preference is given to commands from the automatic systems. After those commands have been issued, the safety systems are automatically taken out of the hands of the operators (or of commands opening or closing control circuits in the case of fire), or the operators may be permitted to intervene when the technological parameters permit giving such permission. A structural diagram of a safety system for an AES with a VVER-1000 is given in Figure 1.

Figure 1. Structural Diagram of AES Safety Systems



Key:
1. Reactor and circulation loops
2. System 1 water supply
3. System 1 power supply
4. System 2 water supply
5. System 2 power supply
6. System 3 water supply
7. System 3 power supply
8. System 1 technological mechanisms
9. System 2 technological mechanisms
10. System 3 technological mechanisms
11. System 1 technological mechanism automatic start
12. System 1 automatic start command initiated
13. System 2 technological mechanism automatic start
14. System 2 automatic start command initiated
15. System 3 technological mechanism automatic start
16. System 3 automatic start command initiated
17. No 1 control post for systems 1-3 (power unit control panel)
18. No 2 control post for systems 1-3 (reactor control panel)

The high demands made on reliability of the AES safety systems have led to the necessity of heavy redundancy of these systems. Thus, the basic systems participating in emergency cooling of the reactor active zone have a 200-percent reserve, that is, three systems, each of which can overcome emergency situations. The same applies not only to the technological portion of these systems, but also to other parts (diesel units, feed and control panels, cables, and so forth). The systems are completely independent of one another, both technologically and physically.

Where these systems cannot be dispersed spatially, the structures separating them are intended to be fire-resistant for a minimum of 1.5 hours. A safety systems flow line diagram is shown in Figure 2 [following page].

In case of an accident involving loss of coolant from the circulation loop, the reactor active zone is cooled with water which can be supplied by high or low pressure pumps from reservoirs under nitrogen pressure. When coolant is lost, the high-pressure pumps are switched on at slow speed. In the case of serious depressurization, up to and including complete, instantaneous failure of the main circulation loop pipeline, water is initially fed from a reservoir and then the high-pressure pumps are switched on; if they are inadequate to maintain pressure in the loop, the low-pressure pumps are switched on. Initially, after an accident, the pumps take water from tanks, but then they are switched over to areaways and the water begins circulating in a closed loop: areaway - heat exchanger - pump - reactor - areaway. Steam generated when coolant escapes from a loop into the premises is condensed using the sprinkler systems.

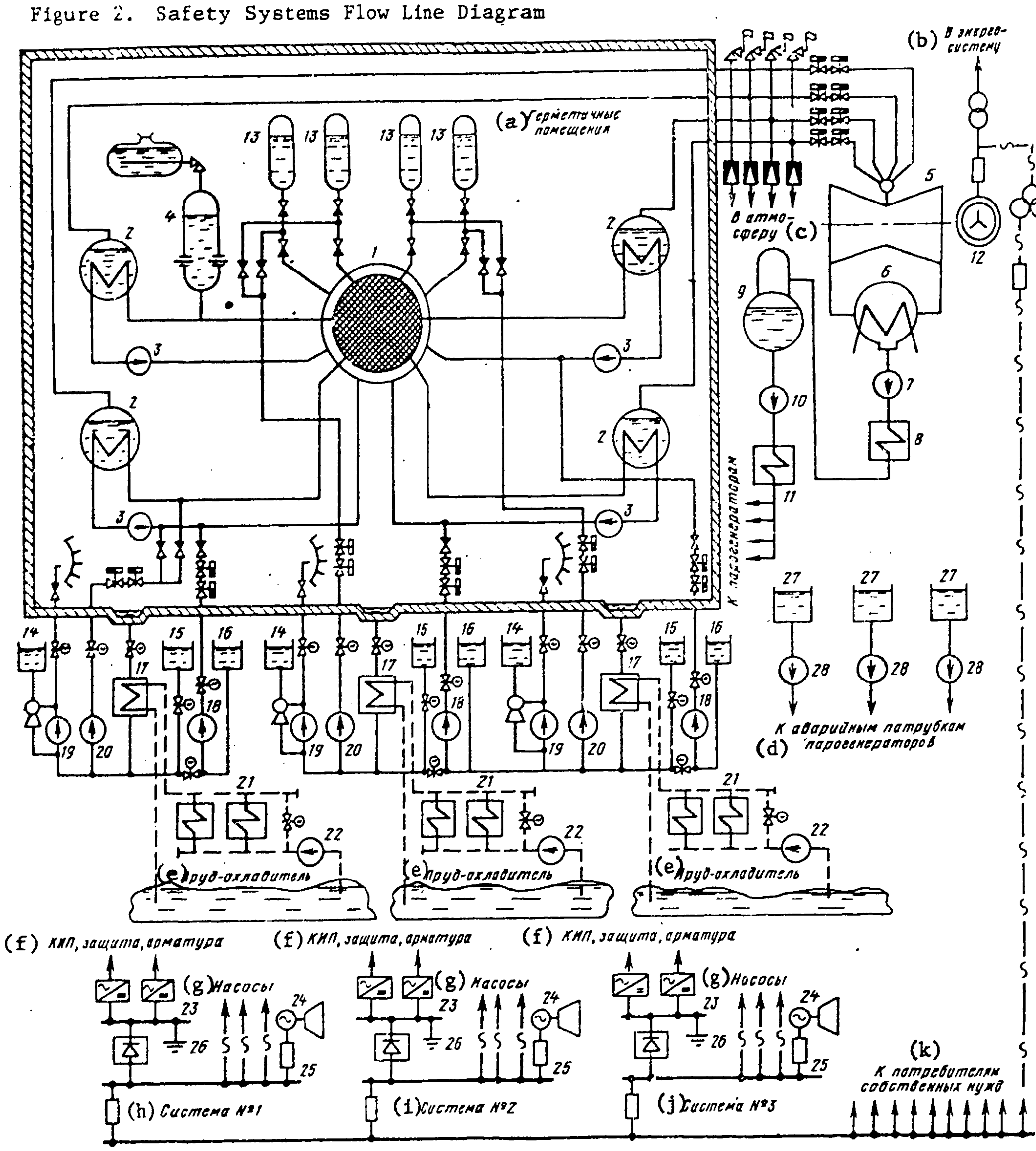
In case of an accident involving loss of feed water to the steam generators, three emergency feed pumps are planned for the AES.

The main AES buildings are also laid out with consideration of safety requirements. Practically all the systems associated with AES safety except for the diesel units and coolant water pumping are laid out on a single foundation slab. Utility lines are laid underground between the reactor building and the diesel and coolant pumping areas. Such an arrangement has advantages over one in which the systems are located in different buildings. A compact placement of systems simplified servicing and eliminates the possibility that personnel not directly connected with safety system servicing will have access to them. Utility line length is reduced to a minimum. Having a single foundation slab simplifies solving AES seismic stability problems.

Locating safety systems in a building built around the reactor pressurization chamber enables us to avoid planning that building for aircraft impact, since a minimum of one of the three systems will always remain in the "shadow" of the pressurization chamber, which is built to withstand aircraft impact.

Construction and operation experience has demonstrated the appropriateness of building AES's in the form of separate power units with minimum technological links to one another and with almost no structural links. When this is done, we can change over to construction using a flow-line method (when several identical power units are located at one AES), ensure a broad work front, and avoid operation of one unit while another is being built. All this speeds up construction and lowers its cost. The operation of individual units is also simplified, inasmuch as it becomes possible to totally exclude interference associated with the construction of some power units and the operation of others. In view of what has been said here, we plan to

Figure 2. Safety Systems Flow Line Diagram



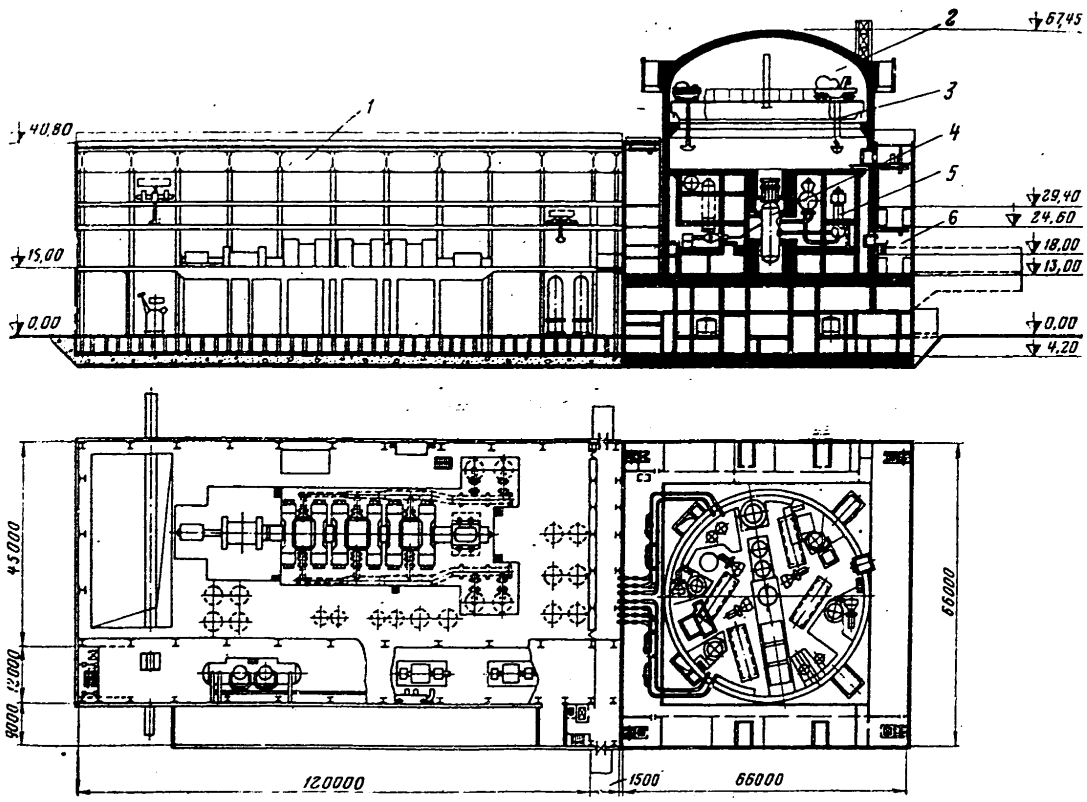
[Key on following page]

build VVER-1000 AES's primarily in the form of individual power units in the forthcoming five-year plan. A line drawing of a VVER-1000 AES layout is given in Figure 3 [second page following].

Key [to Figure 2, preceding page]:

a. Pressurized area
b. To the power system
c. To the atmosphere
d. To the steam generator emergency branch pipes
e. Cooling pond
f. Control and measuring instruments, shield, reinforcement
g. Pumps
h. System 1
i. System 2
j. System 3
k. To own-needs customers
1. Reactor
2. Steam generator
3. Main circulation pump
4. Volume compensator
5. Turbine
6. Condensator
7. Condensate pump
8. Low-pressure heater group
9. Deaerator
10. Feed pump
11. High-pressure heater group
12. Generator
13. Water storage tank
14. Hydrazine-hydrate reserve tank
15. Emergency boron solution tank
16. Boron concentrate reserve tank
17. Heat exchanger
18. High-pressure pump
19. Sprinkler pump
20. Low-pressure pump
21. Coolant water consumers
22. Coolant water pump
23. Power supply busbars of Category I reliability
24. Diesel generator
25. Power supply busbars of Category II reliability
26. Storage battery
27. Desalinated water reserve tank
28. Emergency feed pump

Figure 3. Layout of the Main Structure of a VVER-1000 AES



Key:
1. Turbine department
2. Reactor building
3. Crane
4. Reactor
5. Main circulation pump
6. Auxiliary premises

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ARMENIAN AES SEISMIC STABILITY

Moscow TEPLOENERGETIKA in Russian No 10, Oct 80 pp 21-24

[Article by Engineers R. S. Galechyan and E. S. Saakov and Candidate of Physico-mathematical Sciences K. A. Gazaryan (Armenian AES): "Main Features of Seismic Stability of the Armenian Nuclear Power Plant"]

[Text] The Armenian AES was the first nuclear power plant built in the USSR in a region of high seismic activity. Nuclear power plants in seismic zones require an extremely responsible approach to ensure safety and cannot be planned following general construction norms and regulations.

The planning assignment for the first line was developed in 1968 by the nuclear power engineering department at "Teploelektroproyekt" Institute based on the plan for the third power unit at Novovoronezhskaya AES, with its series-produced VVER-440 units. Lack of experience in building AES's in seismic regions prevented the planning assignment for the Armenian AES from reflecting sufficiently fully the technical resolution on ensuring seismic stability.

The planning organization (the Gor'kiy department of "Teploelektroproyekt" Institute) developed "Measures to Ensure Seismic Stability at the Armenian AES Using Series-Produced VVER-440 Units" in 1971 with consideration of the recommendations of construction, design and scientific research organizations; these measures were used for guidance in the actual planning.

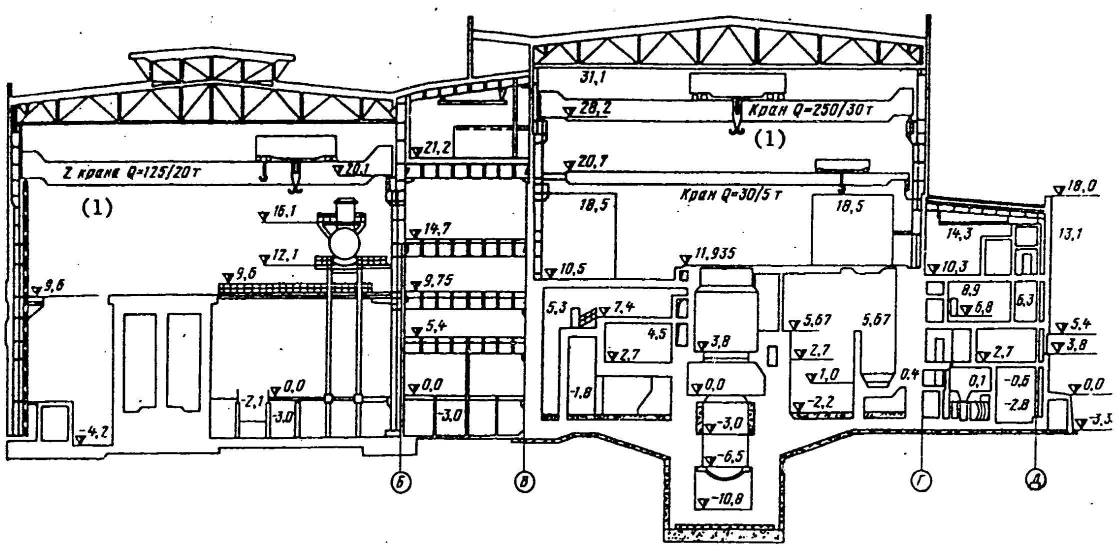
In order to ensure that operator personnel and the population at large are protected against radiation, as well as to avoid possible economic loss as a result of tremors, all systems and components are subdivided into three categories, with different demands as to maintaining operability: Category I -- systems and components which ensure AES safety during and after an earthquake, that is, shutting down the reactor and keeping it shut down, reactor cooling, localizing any damage (to the reactor, control and safety rods, concrete shield, first-loop equipment and pipelines, box pressurization loop, boron assembly and emergency replenishment equipment, emergency replenishment localization system, damage localization system, diesel generator station); Category II -- systems and components ensuring AES operability without significant interruption, protection of expensive equipment and radioactivity containment if the radiation might lead to overexposure of personnel but which does not threaten the population at large (the special water treatment installation and the first-loop auxiliary equipment, deaerators, secure feed systems equipment, construction components of the main structure, turbine generator foundation); Category III -- all other AES systems and components.

Main Features of the Armenian AES

Based on an analysis of geologic-physical and engineering-seismological research on the AES site and also on data on strong earth tremors previously observed in this region, the Institute of Geophysics and Engineering Seismology (IGIS) of the Armenian SSR Academy of Sciences issued parameters and a schedule of earthquake recurrence. It follows from these data that the Armenian AES would be built on a site where the maximum earthquake expected would be 8.0, so the calculated earth tremor used in the planning was 10.

A cross-section of the main AES structure is given in Figure 1. All building parts are based on industrial facility seismic-stability construction norms with a safety factor of four for the reactor department and of two for other installations of the main structure.

Figure 1. Cross-Section of the Main Structure of the Armenian AES



Key:
1. Crane(s)

The reactor, the first-loop equipment, the steam generators and the main circulation pump were designed for seismic events with a safety factor of three.

A series-produced reactor was modernized to increase its seismic stability; the vessel flange has an upper support ring to stabilize it in a concrete shaft against destabilizing moment; to eliminate stresses on subassemblies connecting the ARK [probably: nuclear reactor vessel] jacket pipes with the spherical cover connectors, spacer grates were installed at three heights on the upper block and the ARK jackets were separated by wedges; the crate was secured at two different heights; the reactor support beam is an embedded eqrthquake-resistant metal structure built rigidly into the reactor shaft.

In order to dampen seismic swaying of equipment in the main circulation structure, which has no rigid attachment to structural components due to its thermal displacements, 20-, 100- and 170-ton hydraulic shock absorbers (Figure 2 [following page]) were used to relieve the stress on the main circulation pipelines, D_y=500 mm. They do not prevent thermal expansion but are rigid supports in the event of seismic disturbances.

Research on the dynamic characteristics of this three-dimensional system and stresses in it was done using models on a vibration platform.

Based on these experiments, in order to increase reliability, each steam generator is separated using eight hydraulic shock absorbers, each main circulation pump by three and each GZZ [not further identified] by two.

The seismic stability of the common industrial fittings used in Category I systems was calculated and the ability of the fittings to hold under vibration was determined on vibration test stands.

Utility lines at the AES site (diesel fuel pipelines, oil lines, acetylene, oxygen and water pipelines) were made to conform to special specifications for laying pipelines in seismic regions.

Control and measuring devices, automatic control apparatus, electrical devices and equipment used to control, monitor and feed Category I technological equipment are also included in Category I.

Using a specially developed program, equipment and apparatus was tested at manufacturing plants and on vibration test stands of the IGIS, Armenian AES and All-Union Scientific Research Institute of Hydraulic Engineering imeni B. Ye. Vedneyev for the predicted parameters of possible earthquakes (speed, frequency, amplitude).

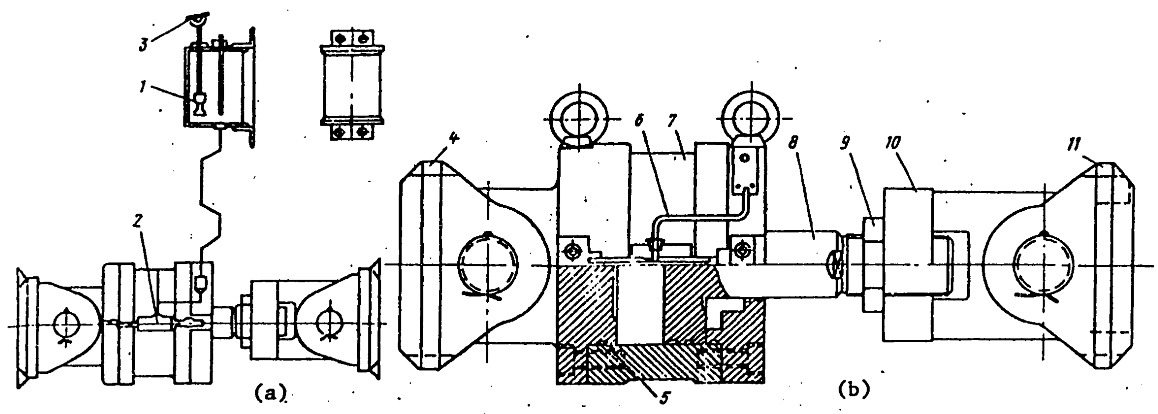
On the basis of an analysis of this research, control and safety rod boards and panels and electrical equipment were separated to increase AES safety; all electrical equipment and damper assemblies were placed on lower levels, where they would experience less earthquake effects; emergency shut-down cooling control and monitoring are concentrated at a separate control board.

In order to ensure a reliable supply of cooling water to Category I consumers, two earthquate-resistant pipelines were run for industrial water from the pump station to the boron subassembly of each block and the diesel generator station.

If a seismic disturbance disrupts operation of the feed water standard system, chemically desalinated water is supplied through pipelines connected to each steam generator to maintain the water level in the steam generators.

Water is supplied by two additional emergency seismic pumps (ASN) installed in earthquake-resistent premises and using two earthquake-resistant tanks of reserve chemically desalinated water. In this regard, steam is discharged into the atmosphere through a contactless relay from the steam generators. After 5-8 hours of operation

Figure 2. Diagram of the Hydraulic Shock Absorber Installation (a) and Overview (b)



Key:
1. Oil tank
2. Hydraulic shock absorber travel control valve
3. Oil level sender
4. Attachment to equipment
5. Gasket
6. From oil tank
7. Cylinder housing
8. Rod and piston
9. Adjustment nut
10. Connecting link
11. Attachment to building component

under these conditions, until the pressure in the steam generators reaches 0.5 MPa, the steam is fed into two emergency condensers (() cooled by industrial water. From the AK's, the condensate is returned to the steam generators using two emergency condensate pumps (AKN), that is, the cooling is done in a closed circuit.

An emergency industrial antiseismic protection system (SIAZ) consisting of three sets of seismometers scattered around the AES site has been installed. The SIAZ system switches on first-order emergency protection when an earthquake of 6 or more strikes. Using a remote-controlled armature, it cuts Category I systems which are not earthquake resistant off from the first and second loops, cuts nonpriority consumers off from the own needs system, puts certain systems participating in power plant emergency operating conditions on stand-by.

Planning the systems and equipment caused serious difficulties due to the complexity of determining the seismic load and calculation schemes, as well as to the inadequacy of experimental data on the behavior of the installation and equipment during earthquakes. In order to record accelerations and shifts during seismic events in specified main-structure building subassemblies and first-loop turbine and equipment foundations, a 21st seismometric post was installed as part of the engineering-seismometry station (ISS) system.

The seismometry laboratory services ISS equipment and the SIAZ system and analyzes data received from these systems. Moreover, with the help of displacement sensors installed in the hydraulic shock absorbers and several main-structure sectors, laboratory associates make observations of displacements in them during loop warm-up and cool-down.

Armenian AES Operating Experience. Scientific and Technical Problems.

The Armenian AES first power unit was started up in three stages.

During the first stage, in an emergency shut-down with loss of the primary sources of electric power, residual heat releases were eliminated by switching over to natural water circulation in the first loop, and the permissible power did not exceed 35 percent of nominal. The power unit was operated at this capacity for 44.5 effective days. Considerable time was required for second-stage operation, so opportunities for increasing power unit capacity were sought out. Calculations showed that for operation at 46.5 percent of capacity at reduced first-loop parameters and sliding second-loop parameters, reactor operating safety was not below nominal parameters and 35 percent of capacity. The power unit was operated for 48 effective days under these conditions.

During the second stage, in an emergency shut-down with loss of the primary sources of electric power for AES use, residual heat releases were eliminated during the first 60 seconds using four (two, for worst-case) GTsN-310 main circulation pumps fed from diesel generators operating continuously, with subsequent transfer to natural circulation. Permissible capacity was 90 percent; these operating conditions were mastered on 13 May 1978.

During the third and concluding stage, residual heat releases were eliminated by running out a GTsN-317 inertial main circulating pump, which experiments showed took more than three minutes. These operating conditions were mastered on 6 October 1979.

The results of tests of the new earthquake-resistant equipment, experiments conducted during the course of mastering 100 percent of capacity and experience in operating at nominal capacity permitted the conclusion that the planning resolutions selected were correct and that the equipment operated reliably. All decisions made on increasing the seismic stability of equipment for the first power unit were implemented in the second unit, which was switched into the network on 29 December 1979 and run at nominal capacity on 31 May 1980.

While the first power unit was operating (December 1976) there were seven earthquakes of 3-5 points at the Armenian AES site. Some of these earthquakes (7 March 1978, 5 points at the epicenter and 4 points in the Armenian AES region; 26 May 1978, 7 and 4 points, respectively; 15 August 1978, 5 and 3 points) were recorded by the Armenian AES engineering-seismometry station and the response of the buildings and equipment was also recorded. The earthquakes had no effect whatsoever on equipment operation.

In view of the positive experience already available in predicting the place, force and time of earthquakes, it seems appropriate to create an experimental-methods testing ground in the region in which the Armenian AES is situated. Clearly an accurate earthquake prediction will enable us to take prompt steps to increase AES operating reliability.

Several technical problems requiring solution were revealed during operation of the AES's first and second power units. Several of them have already been solved, and others require detailed study and development, with the involvement of various organizations. The latter include:

1. Possible substitution of a water cooling system for the GTsN-317 oil cooling system;
2. Improving the seal water supply.

According to the plan diagram, seal water for the GTsN-317 is supplied by piston-type Tr 6/160 pumps. They have a limited operating life and high pressure pulsation (1 MPa), which leads to vibration of the pipelines and equipment. They should be replaced by low-feed centrifuge pumps in continuous operation.

3. Improving hydraulic shock absorber operation. The gasket rings on hydraulic shock absorbers located in the box are made of a special type of rubber; they malfunction, harden, and hydraulic fluid leaks appear. Connecting pipe welds are very weak and the connection system is complicated.

Experience in operating the Armenian AES testifies to the fact that the available systems ensure AES operating safety under seismic conditions.

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PETROLEUM-BEARING PROSPECTS OF SOUTH CASPIAN BASIN

Moscow IZVESTIYA AKADEMII NAUK SSSR: SERIYA GEOLOGICHESKAYA in Russian No 8, Aug 80 pp 133-141

[Article by M. M. Grachevskiy, Ye. V. Kucheruk, I. A. Skvortsov, and A. K. Zyubko: "The Reef Slope of the South Caspian Basin and Its Petroleum and Gas Prospects (Southwestern Turkmenistan)"]

[Text] Many petroleum and gas deposits identified both in the USSR and abroad are associated with buried reefs. A significant share of world reserves of carbohydrates enclosed in reefs are in the barrier reefs, which in most cases form independent zones of petroleum and gas accumulation (Grachevskiy et al., 1977). There is no doubt that many petroleum and gas deposits which will be found in the near future are associated with barrier reefs, which are widespread in numerous known and promising petroleum-gas regions of the USSR. Reef formations are also an important reserve for increasing petroleum and gas extraction and enlarging the reserves of these minerals in both new and old petroleum-gas regions. Prospecting for buried barrier reefs is very timely in our country. Scientifically substantiated prediction of barrier reef zones can often be accomplished by comparative analysis of features of the geological structure and history of development of petroleum-gas basins (Grachevskiy, 1961, 1974). The discovery of buried barrier reefs makes it possible to reorient prospecting and exploration for petroleum and gas and in most cases sharply increases their effectiveness.

The assumption that there is a Neocomian barrier reef slope scarp in Southwestern Turkmenistan was first made on the basis of results of reinterpretation of data from regional KMPV (correlation refracted wave technique) work and a comparative paleogeomorphological analysis of three basins with similar structure: the South Caspian, the Gulf of Mexico, and the Caspian (Grachevskiy, Kucheruk, 1978). Additional analysis of geological-geophysical findings done by the authors of the present article confirms this assumption and indicates a coincidence in plan of a barrier reef scarp of Neocomian age with the Pribalkhanskaya petroleum-gas zone and with the zone of the so-called Shordzh-Gekchinskiy fault (see Figure 1) It is overlain by an argillaceous diapiric ridge and in the Pribalkhanskaya uplift zone controls the processes of diapirism, structure formation, and petroleum-gas accumulation. The faults here are also caused by the argillaceous

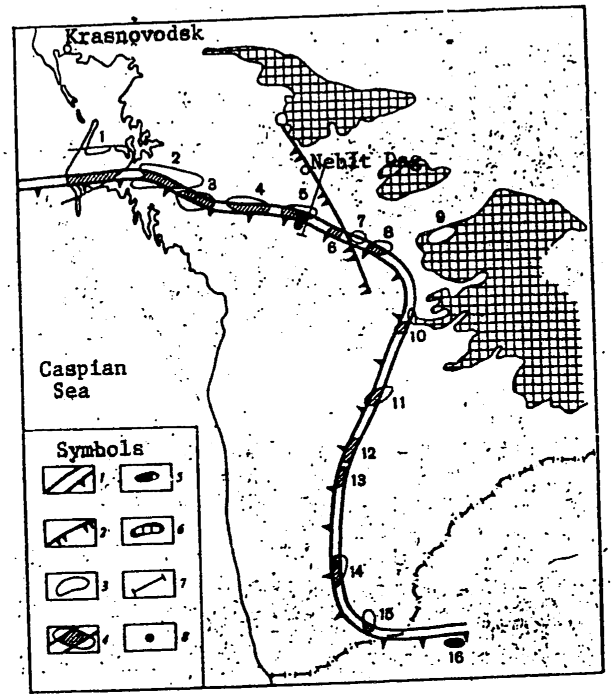

Figure 1. Map of the Distribution of the Potential Petroleum-Gas Bearing Barrier Reef in Southwestern Turkmenistan.

Key to Symbols: (1) Neocomian Barrier Reef (Arrow Point Indicates Its Steep Basin Slope);
(2) Basin Slope of Upper Jurassic Barrier Reef;
(3) Local Uplifts in Zone of Neocomian Barrier Reef [See key to locations below];
(4) Assumed Combined Traps in Barrier Reef;
(5) Gas Deposits in Carbonate Neocomian;
(6) Mining Structures;
(7) Location of Seismogeological Cross-Section of Barrier Reefs in Monzhukly Region (See Figure 2b below);
(8) Recommended Parametric Wells.

Key to Locations Along Reef Line:
(1) Cheleken;
(2) Kotur-Tepe;
(3) Barsa-Gel'mes;
(4) Burun — Nebit-Dag;
(5) Monzhukly, Urundzhuk;
(6) Kum-Dag;
(7) Kobek;
(8) Syrtlany;
(9) Danata;
(10) Western Zirik;
(11) Western Ala-Dag;
(12) Northern Rustam-Kala;
(13) Southern Rustam-Kala;
(14) Gechka;
(15) Togolok;
(16) Kizyl'Tepkh.

diapirs above the reef and disappear beneath the red bed stratum. Finds of organogenic cavernous limestones with fauna of Mesozoic age (Tithonian — Barremian) containing selvages of petroleum, and Domanik-type depression facies in the breccia of the mud volcano Aligul in Cheleken permit the assumption that the source of petroleum in the Pliocene beds of the Pribalkhanskaya producing zone are formations of Mesozoic depression facies and that the principal reserves are contained in the Neocomian barrier reef. In a similar way, at the Mexican Samaria deposit petroleum was first taken only from terrigenous Miocene formations, whereas the principal reserves proved to be associated with the underlying carbonate barrier reef complex of the Reforma trend (1.4 billion tons) lying at a depth of 4,000 meters and also having a Lower Cretaceous age. The discovery of this highly productive barrier reef trend has enabled Mexico not only to fully satisfy its own domestic petroleum needs but also to begin exporting to other countries. As a result of bringing the reef deposits of the Reforma trend into production, petroleum extraction in the country has increased 300 percent in the last five years. According to estimates by experts, in 1988 Mexico will export as much petroleum as Iran exports today. Predicted petroleum reserves are steadily increasing in that country. At the beginning of 1977 they were equal to the reserves of the northern slope of Alaska; by the beginning of 1978 they had reached the magnitude of the reserves of Kuwait, and by September 1978 were being compared with the reserves of Saudi Arabia (Metz, 1978).

The paleogeomorphological similarity of the South Caspian petroleum-gas basin and the Gulf of Mexico basin lies in the fact that both basins are framed by carbonate formations of a lagoon-type paleoshelf bounded on the basin side by barrier reef scarps. These scarps have been studied thoroughly in the Gulf of Mexico basin, where their maximum height is about 5,000 meters ($J_3 - K_1P_1$). On the southern flank of the Bol'shoy Balkhan the thickness of the carbonate Neocomian alone is 450—500 meters and together with the primarily carbonate Upper Jurassic it approaches 1,200 meters. The Danata well (800 meters) has penetrated the carbonate shelf Malm-Neocomian in the foothills of the Western Kopetdag. According to the findings of P. I. Kalugin, the thickness of the reefogenic Goterivian is 400 meters. In the deep Kizyl-Tepekh-2 well drilled on the Gorgan coastal plane in Northern Iran, hydrocarbon gas has been obtained from the Neocomian carbonate stratum that is a component of the Tehran suite. This stratum is composed of porous oolitic limestones (185 meters thick) and evidently, judging from the fact that it contains the deep-water fauna Nannoconus, is a facies of the foot of the reef. The thick layer of Valangian-Goterivian (? 1,500 meters) underlying it, unlike formations of the same age expressed by continental beds that have developed in regions further east, is also a deep-water formation, to judge by the presence of Tintinnadae fauna in it (Jaafari, Chadimi, 1972). This is evidence of the existence of a deep-sea regime in the South Caspian Basin during the Mesozoic. The geomorphological expression of the South Caspian Basin in Barremian is confirmed by the fact that the Urgonian rudistid coral reef facies is confined entirely to its periphery (Bol'shoy and Malyy Balkhan) and the absence of this facies over the vast area of the anhydrite-carbonate lagoon-type paleoshelf within the southern slopes of the Turanian platform plate, where only Bryozoan biostromes are known, as for example at the Modar deposit (Bliskavka et al., 1969).

The paleogeomorphological comparison of the Reforma petroleum-gas zone in Mexico and the Pribalkhanskaya zone of Southwestern Turkmenistan shown in Figure 2 below confirms that they are similar in significant ways. Two zones of barrier reefs and two corresponding zones of lagoons can be traced, deep outer zones and shallow inner zones with anhydrites and gypsums. The outer reefs are correspondingly double-sloped while the inner reefs are virtually single-sloped. There is a one-to-one ratio between the vertical and horizontal scales on the profiles. The Cretaceous reefs of the Pribalkhanskaya scarp of Southwestern Turkmenistan are not completely synchronous; the inner barrier formed somewhat later than the outer and is shifted transgressively in relation to the Upper Jurassic barrier that controls its location. The outer Neocomian barrier is controlled by the lip of a terrigenous argillaceous terrace and developed initially as a single-sloped barrier somewhat further east, in the Kobek region; with the disappearance of this wedge-shaped terrace these barriers are converging and becoming transgressively situated (see Figure 1 above). Under the conditions of Sitio Grande and Sabancuy the Lower Cretaceous inner barrier, judging by the profile, is also controlled by a wedge-shaped Jurassic terrace, evidently of reef origin. Judging by the latest publication on the deposits of Agave, Oxicaca, Artes, Sunap, and Copano, this inner barrier reef is Upper Jurassic-Lower Cretaceous in age and its productive part reaches a thickness of up to 1,500 meters (Dias Serrano, 1978).

The assumptions of Mexican geologists that the outer and inner reef barriers spread completely around the Yucatan Peninsula and that it is a mega-atoll have not been rigorously proven, even though such a double Lower Cretaceous barrier has been outlined for the Belize region (Nava Garcia, 1978).

Under these conditions, as in Southwestern Turkmenistan as well, there may possibly be both regressive displacement and also overlapping or even transgressive displacement on the plane of different-aged reefs, in particular the Cretaceous and Upper Jurassic (under the conditions of the Yucatan Peninsula the Lower Cretaceous and Paleocene). The Paleocene age of the producing horizons of the Chac and other offshore deposits has recently been denied, without solid grounds, by various Mexican investigators even though the distribution of the Paleocene carbonate facies in Yucatan and adjacent regions was demonstrated in earlier works (Judoley, Furrezola-Bermudes, 1971). At the same time, the existence of an independent petroleum bearing Paleocene barrier reef zone here is entirely natural and was essentially predicted by us before it was discovered (Grachevskiy et al., 1977). The presence of Paleocene reefs is also possible in the slope zone of the South Caspian Basin.

In the inner parts of the South Caspian and Mexican basins the thickness of the sedimentary mantle increases to 20 kilometers and the granite crust thins out substantially or even disappears completely with the development of a mantle diapir. Corresponding to the ocean type of crust here is the ocean type of paleobasin with bathyal petroleum-source formations of the Domanik (euxinic) type in the phase of lack of compensation for the depression cycle of sedimentation. Such formations are reliably known from drilling data in the Mexican and Caspian and, judging by presence in the breccia of the mud volcano Aligul, may with full substantiation be assumed in the Malm-Neocomian

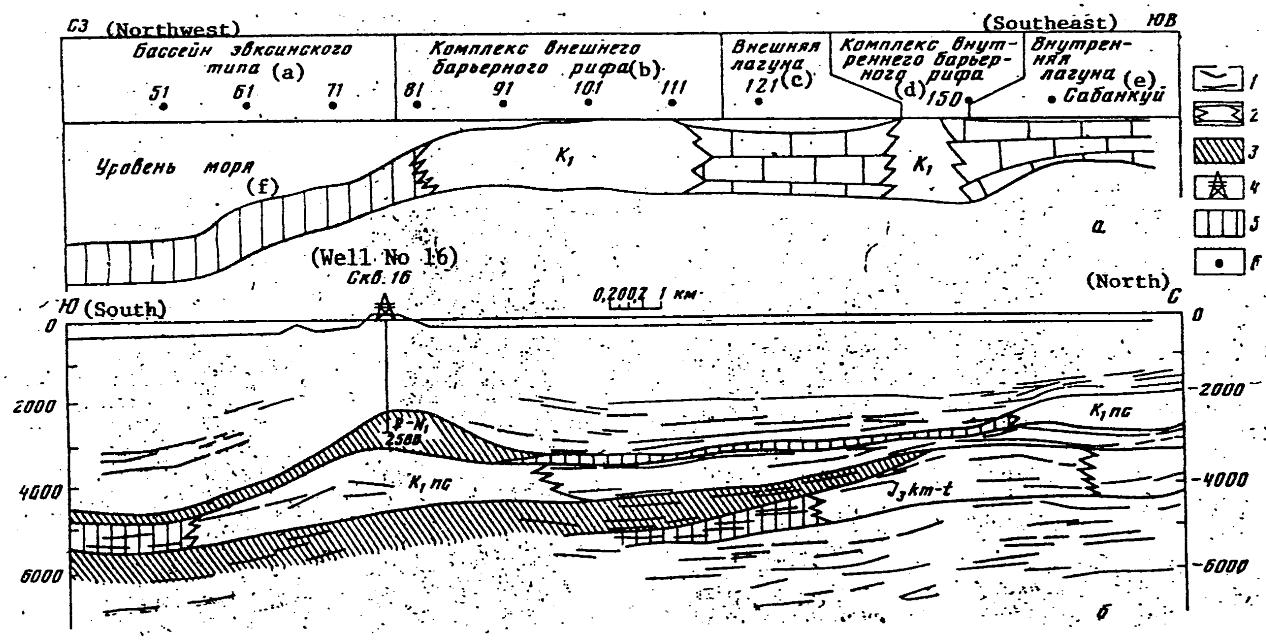

Figure 2. Paleogeomorphological Comparison of the Slope Zones of the Basins of the Gulf of Mexico and South Caspian: (a) Simplified Paleosedimentation Cross-Section of Lower Cretaceous Barrier Reefs of the Sitio Grande Deposit (Reforma Zone in Southeastern Mexico), According to A. Flores Vargas, 1978; (b) Geological-Geophysical Cross-Section of Lower Cretaceous and Upper Jurassic Barrier Reefs in the Monzhukly Region (Southwestern Turkmenistan).

Key: (1) Reflecting Surfaces;
(2) Barrier Reef Complex, including pediment in front of reef and rear facies of reef;
(3) Argillaceous Fill Strata (Diapir- and Terrace-Forming);
(4) Exploratory Well; (5) Domanik-Type High-Bituminous Shales (Petroleum-Gas Source);
(6) Producing Wells; (a) Euxinic Basin: (b) Complex of Inner Barrier Reef;
(c) Outer Lagoon; (d) Complex of Inner Barrier Reef;
(e) Inner Lagoon, Sabancuy; (f) Sealevel.

complex of the South Caspian basin and, in part, in the Upper Cretaceous and Paleocene-Eocene. According to the findings of I. Shteklin (1979), the South Caspian basin is a relict of the Paleozoic Tethys or at least of the pre-Lower Jurassic Tethys, judging by data from the Kizyl-Tepekh-2 well, which revealed Lower Jurassic beds in the assumed zone of distribution of oceanic crust.

The leveling out of the South Caspian basin was accomplished on the eastern slope by the argillaceous diapir-forming strata of the Aptian-Cenomanian while in the inner part of the basin it was done by a Paleogene-Miocene-Pontian stratum; today they form the outer and inner diapir zones respectively. The productive red bed stratum and the overlying Akchagyl-Apsheronian form a complex of compensation synclines with a total thickness of up to 10 kilometers. Locally these synclines force the argillaceous beds of the underlying complex out of the cross-section before the reef into adjacent diapirs two kilometers high.

The Pribalkhanskiy scarp is traced by KMPV seismic exploration data in the beds underlying the red beds along a high-speed horizon (5,000-5,600 meters a second) that corresponds to the surface of the carbonate Neocomian. This scarp is bounded on the south by the so-called Kel'korskiy trough. A gently sloping monocline that together with the south-tilting scarp forms the Pribalkhanskaya scarp corresponds to this trough on this seismic horizon.

In a similar way, the submeridional Shordzha-Gekchinskiy high-amplitude scarp forms the boundary on the South Caspian basin side for the Aladag-Messerianskaya scarp, which is composed of a Malm-Neocomian carbonate complex and an Aptian-Cenomanian terrigenous complex.

The wedge-shaped formation of layers in a subparallel system can be clearly traced in the Mesozoic beds of the KMPV regional profiles done by Yu. N. Godin, which are transverse to the scarps and cross Nebit-Dag and Gechka. According to a reinterpretation done with an OGT (common depth point technique) profile and KMPV , the subhorizontal occurrence of the layers in the space of both scarps can be traced somewhere at the level of the foot of the Neocomian, at a depth of about 6-8 kilometers. In Yu. N. Godin's regional geological-geophysical profile through Erdekli — Nebit-Dag the foot of the Mesozoic (in fact the foot of the Neocomian), which is subhorizontally bedded, even has a slight dip to the north in the scarp zone, toward the Bol'shoy Balkhan, unlike the boundary of the Mesozoic and Cenozoic (Beskrovnyy et al., 1963). This is incompatible with traditional notions of the deep faulted nature of the scarp. The diapiric character of the ridges and faults that control the petroleum and gas presence of the red bed stratum is confirmed by the greater thickness of the argillaceous strata and by the development of AVPD (anomalously high layer pressures) and mud volcanism associated with weakly mineralized hydrocarbonate-sodic waters that are forced out of the argillaceous minerals and introduced into overlying strata. But no well there has disclosed the full thickness of the argillaceous beds beneath the red beds, which exceed 1,200-1,500 meters. On the Pribalkhanskaya scarp beyond the limits of the marginal diapiric ridge the argillaceous stratum under the red beds peters out almost entirely.

The carbonate composition of the lower half of the seismic wedge identified here on OGT profiles is indicated by the linear positive gravimetric anomaly (gravimetric scarp) confined to it, despite the development of the diapiric ridge here. Nonetheless, all the diapirs of the Gogran'dag-Okaremskiy region which have developed in the fore-reef (depression) zone of the South Caspian basin where the thickness of the beds synchronous to the barrier reef is sharply reduced are distinguished by negative gravimetric anomalies and lowered thermal anomalies. Unlike the red bed stratum and the agrillaceous strata beneath the red beds the Neocomian carbonate complex has higher density and heat conductivity (Grachevskiy et al, 1979). On Yu. N. Godin's geological-geophysical profile through Erdekali-Nebit-Dag the Mesozoic beds with a density of 2.65 grams per cubic centimeter in the region of the Pribalkhanskaya scarp occurring at a depth of about 3.5 kilometers with a thickness of several thousand kilometers (2,000-3,000 kilometers) are abruptly wedged out to the south by a lowering of the roof. A density of 2.65 grams per cubic centimeter corresponds to carbonate rocks. A density of 2.4 grams per cubic centimeter is accepted for the overlying Cenozoic terrigenous strata. The fact that the dip angle of the roof of the wedge-shaped carbonate complex in the scarp zone is 30 degrees, which is greater than the critical angle of reef formation (six degrees) indicates that the scarp has a reef origin, in the particular case a barrier reef (Grachevskiy, 1976).

It is important to observe that the curve of local Δg in the same profile by Yu. N. Godin shows a gravitational maximum not only on the Pribalkhanskaya scarp (Vyshka), but also to the north, in the region of the Malm reef scarp. Both maximums, which are caused by the anomalous densities of the barrier reef complexes within the sedimentary stratum, the southern Neocomian and northern Neocomian-Upper Jurassic, complicate the major asymmetric regional minimum of the force of gravity in Bouguer reduction which corresponds to the Predbalkhanskiy trough in the structure of the crystalline foundation formed at the point of subduction of ocean crust underneath continental crust (Benioff zone). The latter is confirmed, in the first place, by the abruptly asymmetric character of the minimum of the curve of Δg with the location of the maximum conjugate with the Predbalkhanskiy minimum in the Bol'shoy Balkhan region and a gravity scarp directly south of this maximum; in the second place, by the existence of a focal earthquake surface at the level of the roof of the basalt layer that dips under the Bol'shoy Balkhan (Andreyev, 1953); in the third place, by outcrops of ultrabasic rock in the zone of the deep Krasnovodsk-Balkhan fault (Kuba-Dag), which is associated with the centers of deep-focus earthquakes (100 kilometers).[1]

Very weak "shallow-focus" earthquakes with focus depths of about 10 kilometers are associated with the Pribalkhanskaya scarp are not caused by deep faults (Beskrovnyy et al, 1963), but rather by isostatic extrusion of the argillaceous strata below the red beds from the fore-reef zone of petroleum

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1 Considering the position of the focal surface of earthquakes, it is perhaps more correct to speak of gravitational slippage of the granite layer from the mantle diapir into the seam zone of the Bol'shoy Balkhan as the interior continental "micro-ocean" opens up in place of the split meridian mass. The rifting of the granite slabs in the South Caspian basis is broader and, possibly earlier than in the Kura basin.

and gas formation into the diapiric ridges, above all into the productive ridge above the barrier (Banka LAM-Cheleken — Kumdag) and their replacement in the cross-section by terrigenous red bed and sub-red strata that comprise the compensation syncline complex. In an analogous manner the lateral barrier reef scarp of the Caspian basin formed above the diapiric salt ridge when Kungur salt was forced out of the fore-reef zone by the weight of the Permian-Triassic red bed complex that had accumulated there (in the compensation syncline). In the Antonio Bermudes group of deposits in Mexico (the Reforma Mesozoic barrier reef trend), the presence of anomalously high layer pressures appears also associated with the formation of a diapiric ridge 1,000 meters thick in the Eocene argillaceous beds above the barrier at the same time as layer pressure below, in the reefogenic limestones at a depth of 4,000 meters, corresponds to hydrostatic pressure (Mayerkhoff, 1978). Such a distribution of layer pressures appears to indicate that a diapiric wedge separates the lateral migrational stream of petroleum-gas bearing fluid from the continental depression facies of the nearby fore-reef zone into two streams: above and below the diapir. The diapiric wedge itself is the cause of the anomolously high layer pressures, while its argillaceous variation is also the source of fresh hydrocarbonate-sodic thermal waters and mud volcanism, whose roots are found (in the case of Southwestern Turkmenistan) in the fore-reef depression and pediment zone of the Neocomian barrier reef at a depth of 6-8 kilometers under the thermal screen of the compensation synclines under conditions of geostatic pressure. The latter, with an average density of 2.4 grams per cubic centimeter for overlying rocks, should reach 1,500-2,000 atmospheres in this case.

With this model of petroleum-gas accumulation mud volcanism does not create, but rather destroys deposits that were formed with nearby lateral migration from the fore-reef generation zone. This model can be reconciled with the fact that the breccia of the mud volcano Aligul contains not only its own reef cavernous limestones but also the black siliceous-bituminous beds of depression facies which we discovered there in 1978. They are the stratigraphic analogs of the Neocomian reef complex. The faults, which are traced around the axial part of the structural Pribalkhanskaya zone in the form of a graben, represent a system of axial grabens that complicate the diapiric ridge and, naturally, taper out in the argillaceous beds below the red beds. Incidentally, similar grabens above diapirs are familiar from the salt domes of Emba (Dossor, Makat, and others).

The local structures of the Pribalkahanskaya diapiric ridge represent a combination of it and transfer submeridional structures, which is emphasized by the paired local gravimetric maximums located south of the chain of local structures (Monzhukly, Nebit-Dag, and others) within the compensation syncline and reflecting the position of submeridional structural protuberances. The combined character of the Monzhukly structure, which is intersected by a structural meridional protuberance, is also confirmed by the existence of the North Monzhukly structure and the transverse Bol'shoy Balkhan uplift with an amplitude of 800 meters in the region of the city of Nebit-Dag. Combined traps have been identified in the Neocomian barrier reef at the following sites: Banka, LAM, Cheleken, Kotur-Tepe, Barsa-Gel'mes, Nebit-Dag, Monzhukly, Kum-Dag, Syrtlanli, Western Zirik, Kobek, Western Aladag, Northern and Southern Rustam-Kala, Gechka, and Togolok.

The depth of the reef crest is 3,000-4,500 meters. In the submeridional sector of the barrier reef trend the combined traps are formed where the trend is crossed by the sublatitudinal anticlinal zones of spurs of the Southwestern Kopetdag and coincide with structures mapped at the foot of the red bed stratum and located along the Shordzha-Gekchinskiy scarp. The traps are also of the combined type within the entire Neocomian barrier reef. The depth of the Neocomian reef crest at the Monzhukly site is about 3,000 meters with a width of about five kilometers, while the height of the reef scarp is 1,500 meters and the height of the reverse slope is about 300 meters. The length of the Monzhukly structure is 12 kilometers. The existence of a high-amplitude barrier reef scarp at the Monzhukly site is additionally confirmed by the coincidence here between the gravimetric maximum and the electrical maximum (based on data from vertical electrical sounding) in the cross-section at 3,600 meters. The maximum has a resistance up to 90 ohms and is extended linearly along the strike of the structure maps according to a provisional seismic horizon near the roof of the red bed stratum. Such high electrical resistances and the thermal anomaly appear to reflect not just the carbonate composition and reef character of the collector, but also that it is saturated with petroleum. The Neocomian barrier reef here, as is true along the entire Pribalkhanskaya scarp, occurs on the lip of an argillaceous regressive terrace presumed to be of Valangian age that grew onto the shelf from the Malm barrier reef scarp to the south during the principal phase of folding in the Bol'shoy Balkhan at the dividing point of the Jurassic and Cretaceous (see Figure 2 above).

The paleogeomorphological situation in the South Caspian petroleum-gas basin permits the hypothesis that the slope barrier reef ensemble can be found under the water of the sea and in the Kura basin as well as in Southwestern Turkmenistan. It would appear that the Eocene slope reef established from seismic exploration data in the region of the Muradkhanly deposit in Azerbaijan is related to this reef formation around the basin (Gadzhiyev, Kul'chavin, 1977). The analogy we have drawn between this vast petroleum-gas basin and the basin of the Gulf of Mexico offers a new picture of its development and petroleum-gas promise, replacing the idea of the South Caspian median mass by the development of a mantle diapir and oceanic basin here in the Mesozoic. In the Turkmen part of the South Caspian basin the principal prospects for petroleum and gas are associated with its Neocomian barrier reef slope scarp. In an analogous paleogeomorphological situation a Mesozoic petroleum and gas bearing barrier reef scarp is predicted along the outer margin of the northwestern shelf of the Black Sea.

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